3 SITE SPECIFIC RISK-BASED END STATE DESCRIPTION

This section describes the current state of knowledge regarding the attributes of human-health and ecological risks posed by all known radiological and chemical hazards at LANL. These attributes are grouped as follows:

- physical and surface features to provide perspective on the nature and extent of various hazards in relation to natural and cultural features
- cultural and ecological features to identify potential receptors
- land-ownership to understand the potential limits of institutional controls
- demographics to identify potentially exposed populations

3.1 Physical and Surface Interface

As described in the DOE's *Guidance for Developing a Risk-Based, Site-Specific End State Vision*, the attributes of the physical and surface interface fall into the following categories:

- Administrative
- Transportation and Infrastructure
- Surface Configuration, and
- Hazard Areas of Concern

The maps shown as Figures 3.1a and 3.1b depict these attributes as prescribed by the DOE, for the current state (2003) and the planned end state (2035), respectively. The attributes included on both maps are described, followed by a discussion of the differences between the current state and the end state conditions, some of which are not visible on the prescribed map format.

3.1.1 Administrative

DOE includes the following within the category of Administrative:

- Land owned and/or controlled by governmental entities (municipal, state, federal, or tribal)
- Wildlife and wilderness areas, and
- Historic and cultural resources

State and federal government agencies and local Indian tribes control land surrounding Los Alamos County. Of these, three federal agencies (i.e., Bureau of Indian Affairs, U.S. Forest Service, and Bureau of Land Management) control the majority of land in the area. The Santa Fe National Forest comprises 634,486 hectares (1,567,181 acres) of land in several counties. The Española District of the Santa Fe National Forest includes 142,521 hectares (352,170 acres) that border DOE land to the northwest and southeast.

The Bandelier National Monument borders the southwest portion of the Laboratory complex and is managed by the National Park Service. The monument includes 12,950 hectares (32,000 acres) of land, 9,308 hectares (23,000 acres) of which are designated wilderness. All access major routes to the monument's visitor center pass through or along the Laboratory property. Thirteen Native American Pueblos are located within 80 km (53 mi) of the Laboratory. Each tribe has the rights of sovereign government, with technical and administrative assistance from the Bureau of Indian Affairs. The San Ildefonso Pueblo owns a triangular piece of land that directly borders MDA G within Cañada del Buey to the north of the facility. The total area owned by the Pueblo is 10,600 hectares (26,192 acres). In addition to hunting wildlife for food, Pueblo people also harvest the fruit of piñon and juniper trees indigenous to the area. Hunting and gathering activities occur on the land directly adjacent to Mesita del Buey. There are also tribal sacred areas and ceremonial practices that may affect exposures.

3.1.2 Transportation and Infrastructure

DOE includes the following in the category of Transportation and Infrastructure:

- Highways, roads, and railroads;
- Utility transmission lines;

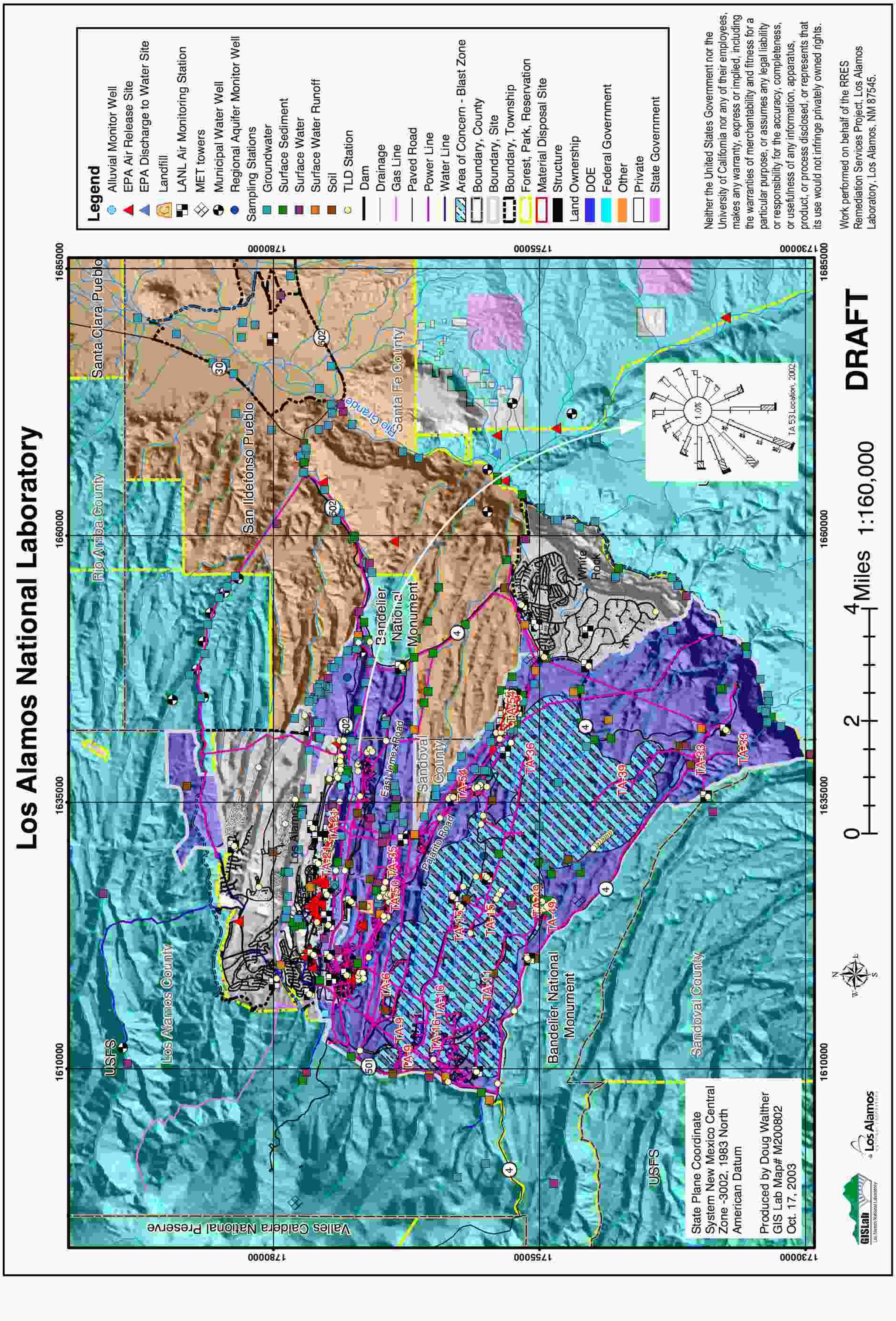


Figure 3.1a. Site physical and surface interface, Current state.

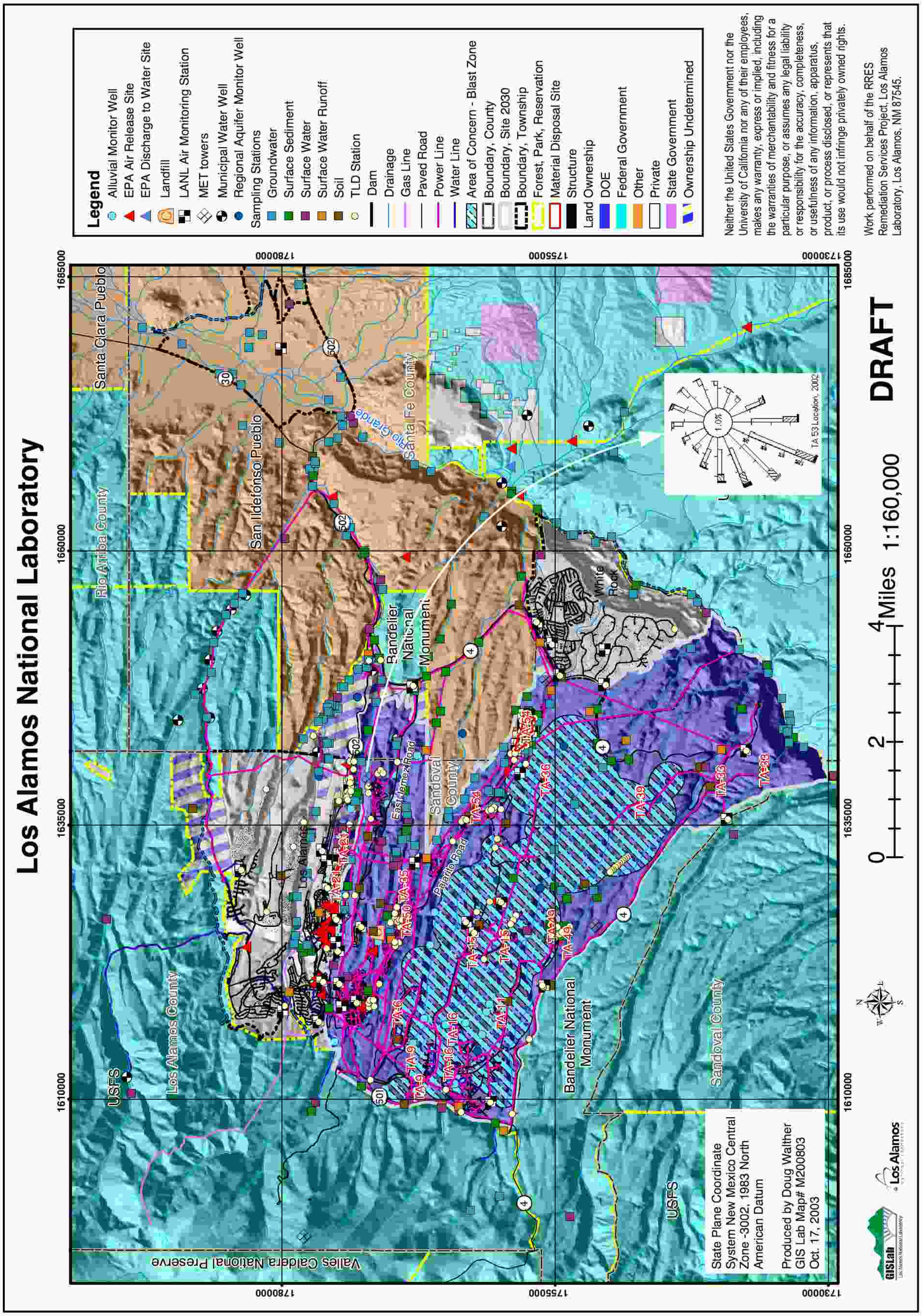


Figure 3.1b. Site physical and surface interface, End state.

- Sewage treatment facilities;
- Landfills; and
- LANL buildings and facilities.

With the exception of LANL buildings and facilities, no information was found to suggest major infrastructure changes between 2003 and 2035. LANL has initiated a major nuclear facilities consolidation program that will result in a dramatic change in the number and location of many of LANL's major buildings and facilities between 2003 and 2035. The data reflecting these changes are included in the maps, although they are not visible on the prescribed map format.

3.1.3 Surface Configuration

Based on DOE guidance, the site-wide Surface Configuration for LANL includes major topography and surface hydrology.

Rivers and streams located within 80 km (53 mi) of the Laboratory include the Rio Grande and its tributaries including the Chama, Ojo Caliente, Santa Cruz, Nambe, and Tesuque rivers to the north and east; the Jemez River and San Antonio creeks to the west; and the Santa Fe and Galisteo rivers to the south. The Rio Grande receives all surface water drainage from the Pajarito Plateau. Reservoirs within 80 km (50 mi) include the Cochiti, Abiquiu, Santa Cruz, and Jemez.

Despite the dramatic erosional topography of the Pajarito Plateau that resulted from greater surface flows in the past, only a few streams currently flow year-round; most flow only after heavy summer monsoonal rains and with spring snowmelt. Run-off from heavy rainfall and snowmelt reaches the Rio Grande several times a year in some watersheds.

Springs occur at elevations between 2,400- and 2,700-m (7,900- and 8,900-ft) on the eastern slopes of the Jemez Mountains and supply water to the upper reaches of several major watersheds. These springs discharge at rates from 7–530 l/min (1.8–140 gal./m), which is insufficient to maintain surface flow for more than the upper third of the watersheds before it is depleted by evaporation to the atmosphere and infiltration into the underlying alluvium. On the mesas, water flows only as stormwater and snowmelt run-off.

3.1.4 Hazard Areas of Concern

As represented in DOE's guidance, Hazard Areas of Concern include attributes contributing to the understanding of LANL hazards and potential exposures. Much of this information derives from the extensive sampling and monitoring conducted by LANL. In fact, the sampling and monitoring locations are among the most visible features on Figures 3.1a and 3.1b.

This section briefly describes the hazards associated with LANL operations and legacy contamination. Following, the current risks associated with both operational hazards and legacy hazards are characterized using recent monitoring data.

3.1.4.1 Operational Hazards

Operational hazards are associated with:

- Nuclear and radiological facilities,
- Biohazard facilities,
- Chemistry facilities, and
- Waste treatment, storage, and disposal facilities,

Currently, LANL has 18 nuclear facilities, as identified and categorized in accordance with the requirements of Title 10 Code of Federal Regulations, Part 830, *Nuclear Safety Management*, Subpart B, "Safety Basis Requirements." For each nuclear facility (which includes buildings, structures and processes), a formal safety analysis has been performed to identify hazards, and appropriate operational safety requirements have been developed to ensure facility safety. The approved safety basis documents for LANL's nuclear facilities ensures that the risks posed by those facilities and the nuclear materials therein are administratively controlled to the extent required by law.

Several of the nuclear facilities are legally permitted through NESHAPS and NPDES to release vapor-phase and effluents into the environment. Important among these are the beryllium machine shops and Radioactive Liquid Waste Treatment Facility. Permitted releases are monitored at points of discharge and at points down-gradient, both on and off site. Monitoring results are reported to the appropriate administrative authority, and are also published in the annual environmental surveillance report required by DOE.

One of LANL's nuclear facilities is a low-level radioactive waste disposal facility, known as Material Disposal Area G, MDA G, or simply Area G. An important part of MDA G's authorization basis is the performance assessment and composite analysis (PA/CA).

The DOE radioactive waste disposal sites are managed, in part, based on whether the sites were active before or after the issuance of DOE Order 5820.2A (September 25, 1988). DOE Order 5820.2A (superceded by DOE Order 435.1 in 2001) requires a radiological PA to demonstrate and document the safety basis for disposal sites accepting low-level radioactive waste (LLW) after September 25, 1988. The order defers radioactive waste disposal sites used before that date to either Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) or Resource Conservation and Recovery Act (RCRA) corrective action, with the latter applying at the Laboratory. To ensure that the cumulative radiological impact of all radioactive waste disposals will not adversely impact human health or the environment for future generations, a composite analysis (CA) is also required by the DOE.

The PA is required to determine if LLW generated since September 26, 1988 has been, and will continue to be, disposed at MDA G in a manner that will not result in radiation doses to the public that exceed performance objectives specified by the DOE. In a complementary fashion, the CA is used to evaluate options for ensuring that exposures from all radioactive waste disposed of at MDA G will not exceed specified limits in the future.

The PA/CA for MDA G is equivalent to a baseline human-health risk assessment for radiological constituents, evaluating environmental fate, transport, and human-health risk consequence of radioactivity disposed there. Consistent with DOE guidance, the all-pathways, all-sources risk analysis covers a time period of 1,000 years post closure.

The performance objectives for the PA that are comparable to RCRA and CERCLA risk assessment requirements are the following:

- Maximum effective dose equivalent of 25 mrem/yr. to any member of the public resulting from external exposure and concentrations of radioactive material released into surface water, groundwater, soil, plants, and animals.
- Maximum effective dose equivalent of 10 mrem/yr. to any member of the public from concentrations of radioactive material released to the atmosphere (excluding radon) from Area G and all other facilities at the Laboratory.
- Maximum effective dose equivalent of 4 mrem/yr. to any member of the public from the consumption of drinking water drawn from wells outside of the land-use boundary.

The performance objective for the CA is the DOE's primary annual dose limit of 100 mrem/yr.

The results of the PA/CA are compared to their associated performance measure in Table 3.1-1. By all measures, the PA/CA provides reasonable assurance that radionuclides released from MDA G will not exceed health-based standards, even when potential interacting releases from legacy MDAs are considered.

Table 3.1-1
Summary results of the MDA G performance assessment/composite analysis

Inventory	Analysis	Calculated Peak Dose	Performance Objective*
PA	Air pathway	6.6×10^{-2} mrem/yr.	10 mrem/yr.
CA	All pathways	5.8 mrem/yr.	30 to 100 mrem/yr.
PA	Groundwater protection	3.5×10^{-5} mrem/yr.	4 mrem/yr.
PA	All pathways	1.0×10^{-4} mrem/yr.	25 mrem/yr.
CA	All pathways	7.2×10^{-3} mrem/yr.	30 to 100 mrem/yr.

In addition to the nuclear facilities listed previously, there are numerous radiological facilities wherein radioactive materials are used, but under conditions that prevent risk-significant exposures. Like nuclear facilities, radiological facilities are identified through a formal process, but are exempt from safety-basis requirements. Still, safe operating procedures are required in radiological facilities to reduce the risk of harmful exposures.

The LANL integrated safety management system includes an authorization-basis requirement for facilities and processes that pose a non-nuclear hazard. Examples of non-nuclear hazards requiring non-nuclear authorization basis prior to initiating work are compressed-gas facilities and chemical operations facilities.

A significant operational hazard is identified over much of the southern portion of the LANL campus (light blue cross-hatching). This is the buffer zone associated with the firing sites, which are core mission facilities. As such, this buffer zone is expected to remain well into the future.

3.1.4.2 Legacy Contamination

Legacy contamination includes all of the sites being investigated and remediated under LANL's EM-sponsored cleanup program. The risk based end state achieved at the completion of the EM mission will ensure that performance standards (including a final site-wide risk goal) are met and maintained. This section briefly describes the general means by which those performance measures will be met to achieve the risk-based end state. The map shown on Figure 3.1b reflects the accomplishment of those general remedies, which include:

- remediation of surface and near-surface contamination to risk-based levels consistent with the planned future land use, either residential (for land parcels transferred to county or tribal governments), recreational (for land parcels transferred to the National Park Service or National Forest Service), or industrial/recreational (for land that will remain under the institutional management of LANL).
- capping and monitoring of MDAs, which will be transferred to NNSA for management.
- A site-wide groundwater monitoring program that will be implemented by NNSA.

Table 3.1-2 lists the number and general description of potential releases sites within each watershed, and indicates the planned remediation strategy and end state. The End State column indicates the planned remediation; the exposure scenarios that will be used in risk assessments supporting remediation plans; and the future landlord.

Table 3.1-2
Planned remediation end state for potential release sites

Watershed	Current Description	Contamination	End State
Los Alamos/Pueblo	63 potential release sites with residual contamination from surface waste disposal, explosives testing, wastewater	Rad, Inorganic, PCBs	Removal/ Based on Residential use soil cleanup levels/ Transfer to LA County or Tribal governments
	136 potential release sites with residual contamination from surface waste disposal, explosives testing, wastewater	Radiologic, Inorganic, Organic, PCBs	Removal/ Cap in place/ Based on Industrial and/or Recreational use soil cleanup levels for NNSA lands/ Monitoring systems installed/ transfer to NNSA
Mortandad	4 potential release sites attributed primarily to discharges of LANL wastewaters, which have occurred since 1951 and possibly as early as 1943, but also from runoff from mesa tops with LANL operations.	Perchlorate, Nitrate, Rad, Inoganic, PCBs	Removal/ Based on Residential use soil cleanup levels/ Transfer to LA County or Tribal governments
	169 potential release sites attributed primarily to discharges of LANL wastewaters, which have occurred since 1951 and possibly as early as 1943, but also from runoff from mesa tops with LANL operations.	Rad, Inorganic, Organic, PCBs	Cap in place/ Removal/ Based on Industrial and/or Recreational levels/ Monitoring systems installed/ transfer ownership to NNSA
Pajarito	172 potential release sites associated with secondary contamination from runoff from mesa-top operations	Rad, HE, Organic, Inorganic, perchlorate	Cap in place/ Removal/ Based on Industrial and/or Recreational levels/ Monitoring systems installed/ transfer ownership to NNSA
Sandia	76 potential release sites primarily associated with industrial and sanitary wastewaters and power plant cooling towerst	Rad, Inorganic, Organic, PCBs	Removal/ Based on Industrial and/or Recreational use soil cleanup levels/ Transfer ownership to NNSA
Water/Cañon de Valle	133 potential release sites primarily contaminated with debris from firing sites	Rad, Inorganic, HE	Removal/ Based on Industrial and/or Recreational use soil cleanup levels/ Transfer ownership to NNSA
Ancho	33 potential release sites primarily contaminated with debris from firing sites	Rad, Inorganic, HE	Removal/ Based on Industrial and/or Recreational use soil cleanup levels/ Transfer ownership to NNSA
Chaquehui	53 potential release sites associated with former firing areas and tritium site operations.	Rad, Inorganic, HE	Removal/ Based on Industrial and/or Recreational use soil cleanup levels/ Transfer ownership to NNSA
Frijoles	15 debris areas located in Bandelier National Monument.	Rad, Inorganic	D&D/ Based on Recreational use soil cleanup levels/ ownership NPS, NFS

Table 3.1-3 lists the legacy MDAs, along with a general description of the site and the planned remedy. The End State column indicates the planned remediation; the exposure scenarios that will be used in risk assessments supporting remediation plans; and the future landlord. The end state for the majority of the

MDAs is capping and monitoring, and transfer to NNSA. These are the sites for which long-term management will be required, as reported in DOE's 2001 *Long-Term Stewardship Study*.

The risk-based remedy-selection process developed for these MDAs is nearly identical to the performance assessment/composite analysis process that established the authorization basis for radioactive waste disposal at LANL's MDA G.[1] Indeed, seven of the legacy-waste MDAs (MDAs A, B, C, T, U, V, and AB) are included in the composite analysis for MDA G.[2] For this reason, LANL expects that the long-term institutional management of the legacy-waste MDAs can be integrated directly into the MDA G performance assessment/composite analysis maintenance program already implemented by NNSA, which is likely to be integrated within the LANL environmental management system.

Table 3.1-3

Planned remediation end state for MDAs

Watershed	**MDA**	**Current Description**	**End State**
Los Alamos/Pueblo	A	1.8-acre; two 50,000-gal. underground tanks and 3 pits	Cap and monitoring in place/ Industrial use/ Transferred to NNSA
	B	6-acre; primarily solid waste in shallow trenches; some chemical waste	Cap and monitoring in place/ Industrial use/ Transferred to NNSA
	T	3.5-acre; four radioactive liquid waste absorption beds and cemented-waste shafts	Cap and monitoring in place/ Industrial use/ Transferred to NNSA
	U	1.3-acre site; two absorption beds and associated sump	Cap and monitoring in place/ Industrial use/ Transferred to NNSA
	V	1-acre; three liquid absorption beds for outflow from radioactive laundry facility	Cap and monitoring in place/ Industrial use/ Transferred to NNSA
Mortandad	C	11.8-acre; 7 pits and 108 shafts with solid radioactive waste	Cap and monitoring in place/ Industrial use/ Transferred to NNSA
	W	Two 4-in. diameter, 125-ft long stainless steel tubes suspended inside 8-in. diameter carbon steel–cased wells; tubes backfilled under pressure with nitrogen and sealed; 150L of liquid sodium reactor coolant contaminated with Pu-239 and associated fission products	Transferred to NNSA
	X	Buried LAPRE II reactor, decommissioned in 1959; site remediated in 1991	Transferred to NNSA
Pajarito	F	Classified trash	Cap and monitoring in place/ Industrial use/ Transferred to NNSA
	G	65-acre; 34 disposal pits, 174 disposal shafts with solid radioactive waste, 4 trenches with transuranic waste	Cap and monitoring in place/ Industrial use/ Transferred to NNSA
	H	0.3-acre; 9 shafts with radioactive and classified waste	Cap and monitoring in place/ Industrial use/ Transferred to NNSA
	I	2.65 acre; solid waste landfill	Transferred to NNSA
	L	2.5-acre; 1 pit, 34 shafts and 3 surface impoundments for liquid chemical waste in	Cap and monitoring in place/ Industrial use/ Transferred to NNSA
	M	Surface trash disposal site	Transferred to NNSA
	Q	Naval guns and other metallic trash	Cap and monitoring in place/ Industrial use/ Transferred to NNSA

[1] LANL provided NMED with a document describing the risk-based corrective action strategy for MDAs in 1999.
[2] Results of the composite analysis indicate that legacy MDAs are as robust as MDA G.

Watershed	MDA	Current Description	End State
Chaquehui	D	Two underground concrete chambers for HE	Transferred to NNSA
	E	Underground chamber plus 6 waste disposal pits; spent projectiles, U, Be	Cap and monitoring in place/ Industrial use/ Transferred to NNSA
	K	Septic tank, sump, roof drain and outfall; contaminants include tritium	Transferred to NNSA
Water/Cañon de Valle	N	< 1 acre; construction and office debris in shallow trenches	Remediated to Industrial and/or Recreational use standards Transferred to NNSA
	P	Surface site; HE burn-ground residues	Transferred to NNSA
	R	Surface site; HE burn ground and associated HE residues	Remediated to Industrial and/ore recreational use standards Transferred to NNSA
	Z	Approximately 2,000 yd of uranium-contaminated firing-site debris	Remediated to Industrial and/or recreational use standards Transferred to NNSA
	AA	13-ft deep trenches with burned and unburned firing site debris	Remediated to Industrial and/or recreational use standards Transferred to NNSA
Ancho	Y	5 shallow trenches with construction, office, and firing-site debris.	Remediated to Industrial and/or Recreational use standards Transferred to NNSA
	AB	Multiple 80-ft deep shafts with residue from noncritical nuclear weapons safety experiments	Cap and monitoring in place base on Industrial use Transferred to NNSA

Table 3.1-4 summarizes the current status of site-wide groundwater contamination and describes the planned remedy. The table includes three categories of groundwater, consistent with the site-wide hydrogeology: Alluvial, Perched, and Regional. The regional aquifer is the only source of drinking water for the local communities; alluvial and perched groundwater is not accessible. The supply wells are on LANL property, but are managed by the County of Los Alamos.

Table 3.1-4
Planned remediation end state for groundwater

Groundwater	Contaminants Detected	Remedy	End State
Alluvial	Nitrates, 15 mg/L Perchlorates, 3 ppb Strontium-90, 15 – 60 pCi/L Tritium, 15,000 pCi/L Molybdenum >1 mg/L	Reactive barriers, source removal, monitored natural attenuation, institutional controls over water use	Reduce contaminant levels for MCLSs or State standards so no 10^{-5} risk occurs in the regional aquifer. Transfer of groundwater monitoring and treatment systems to NNSA
Perched	High Explosives, 50 ppb Nitrates, 15 mg/L Perchlorates, 12 – 142 ppb Tritium 1,200 pCi/L	Institutional controls over the use of water, monitored natural attenuation, monitoring.	Long-term monitoring
Aquifer	High Explosives, 2 – 3 ppb Perchlorates, 6 ppb Nitrate 10 mg/L Tritium 350 pCi/L	Institutional controls over the use of well fields, Monitored natural attenuation, treat at the well head if necessary	Maintain Regional Aquifer as a drinking water supply without exceedences of 10^{-5} risk standards

The regional hydrogeology is being characterized through the installation of 32 wells extending to the regional aquifer. Table 3.1-5 lists the wells installed and planned as part of the regional hydrogeologic characterization program.

Table 3.1-5
Planned regional hydrogeology characterization wells

Watershed	Well
LosAlamos/Pueblo	R-5
	R-9
	R-7
	R-1
	R-8
	R-2
	R-3
	R-4
	R-6
Mortandad	R-15
	R-13
	R-14
	R-16
Water/Cañon de Valle	R-27
	R-28
	R-25
	R-29
	R-26
	R-24
	R-30
Sandia	R-12
	R-10
	R-11
Ancho	R-31
Pajarito	R-19
	R-22
	R-23
	R-18
	R-20
	R-17
	R-32
	R-21

LANL has completed a baseline probabilistic risk assessment and risk-based decision analysis model for Mortandad Canyon.[3] Similar models will be completed for each watershed. The watershed models will than be coupled to produce a site-wide groundwater decision analysis model that will be used to design (following systems-engineering principles) a site-wide monitoring program that will meet all of LANL's

[3] Preliminary results indicate a very low probability of exceeding EPA's threshold Hazard Index value of 1, excess cancer risk of 10^{-5}, or DOE's groundwater dose limit of 4 mrem, assuming a standard 70-year drinking-water exposure over a 100-year modeling period.

monitoring requirements in an integrated and cost-effective manner. Monitoring and monitored natural attenuation are expected to be the primary elements of the remedies for most contaminated groundwater locations at LANL. Ten monitoring wells are planned to fulfill the expected RCRA/HSWA monitoring obligations relative to historic releases and surface waste sites. These wells will monitor contaminant migration and contaminant levels downgradient of key liquid discharge locations, primarily in Los Alamos, Pueblo, Mortandad, and Water Canyons. Where possible, these wells will have supplementary benefits and may serve as multipurpose monitoring wells relative to material disposal areas (MDAs), RCRA units, and groundwater discharge plans. The optimal number and location of a subset of hydrogeologic characterization wells will be identified for long-term performance monitoring in support of EM completion, again using risk-based decision analysis methods.

3.1.4.3 Environmental Monitoring Summary

To ensure compliance with regulations and requirements related to major environmental statutes, LANL routinely monitors for radiation and radioactive and non-radioactive materials in environmental media, at both on- and off-site locations, all of which are identified on Figures 3.1a and 3.1b. Comparing monitoring results with applicable standards, LANL's environmental surveillance report routinely concludes that it is in compliance with all environmental regulations and does not pose a threat to its employees, member of the general public, or the environment. To support these conclusions, LANL completed the EPA OSWER's *Documentation of Environmental Indicator Determination*. These worksheets are included as an appendix to this document.

3.1.5 Significant Differences between the Current State and the End State Maps

The major difference in the attributes considered by DOE to represent Physical and Surface Interfaces now and in the year 2035 that are visible in Figures 3.1a and 3.1b is:

- The change in ownership of land in the north-central and north-northeast site-boundary in 2003 from Government in 2003 (grey outlined purple irregular polygon) to Ownership Undetermined in 2035 (purple cross-hatch), reflecting the planned transfer of land to either Los Alamos County or San Ildefonso Pueblo.

3.2 Human and Ecological Land Use

This section discusses the human and ecological attributes presented in maps following DOE's prescribed format. Figure 3.2a represents current conditions (i.e., 2003), while Figure 3.2b represents end-state conditions (i.e., 2035).

As discussed in DOE's guidance, human and ecological land use attributes fall into the following three categories:

- Human Activities,
- Ecological Activities, and
- Hazard Areas of Concern.

3.2.1 Human Activities

Human activities include site-wide and local land-use and water-use patterns, which can be used to identify potential points, pathways, and scenarios of human exposure to potentially contaminated media. Characteristic differences in human activities (and therefore potential exposures) are expected in agricultural, residential, commercial, industrial, recreational, open-space, and restricted-access areas.

The majority of the land within the LANL boundary (grey line) land is designated as Open Space (dark blue) or Manufacturing and Industrial (magenta). The industrial space is only sparsely populated with buildings and structures associated with LANL operations. While not visible on the prescribed map format, the topography within and around the LANL site effectively limits amount of land suitable for facilities. Generally speaking, LANL buildings are on mesas rather than in canyons. This is also true for residential, municipal, and commercial structures in the Town of Los Alamos. Since the topography of the region is not expected to change significantly between 2003 and 2035, this general rule is expected to hold true.

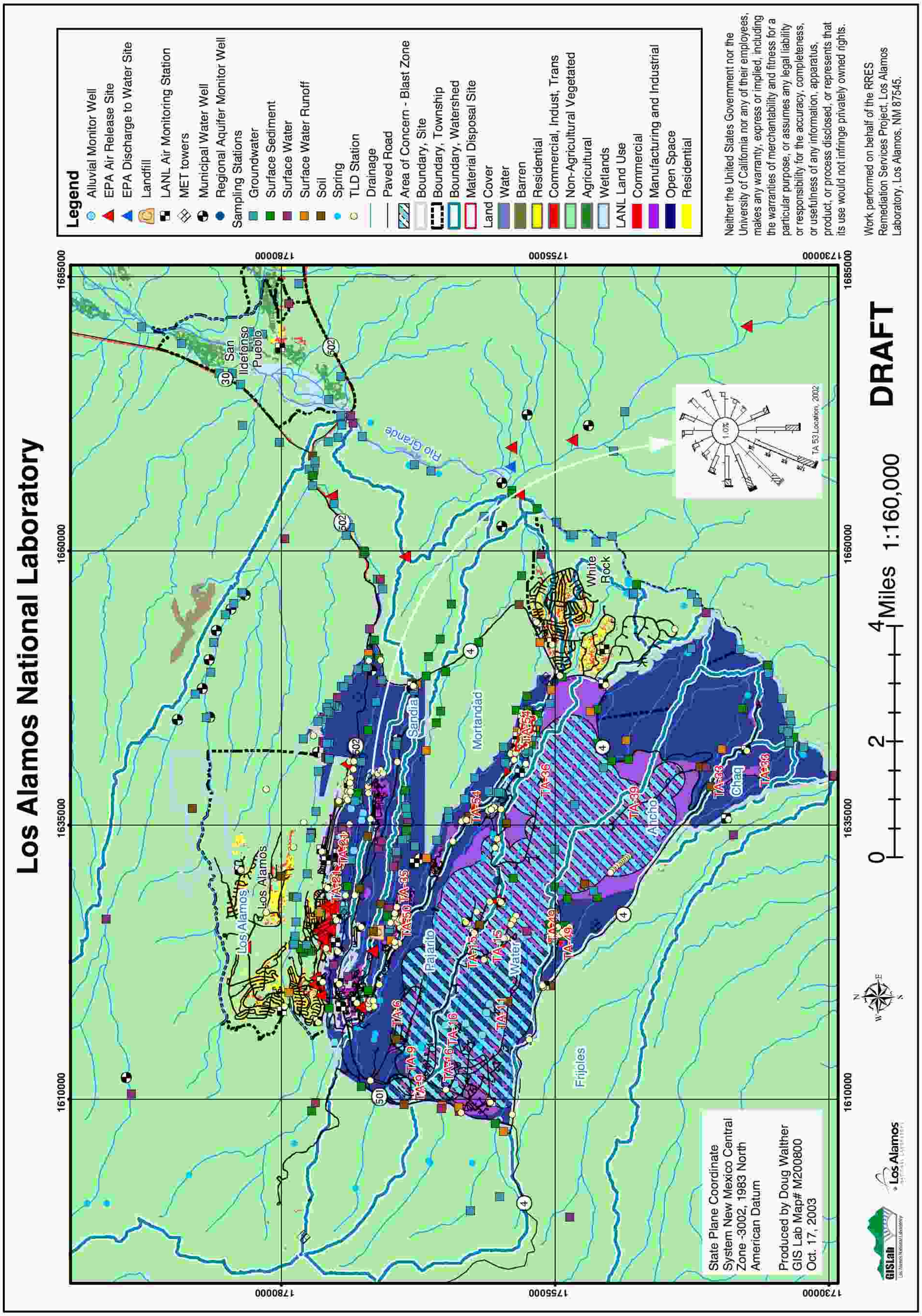


Figure 3.2a. Site human and ecological land use, Current state.

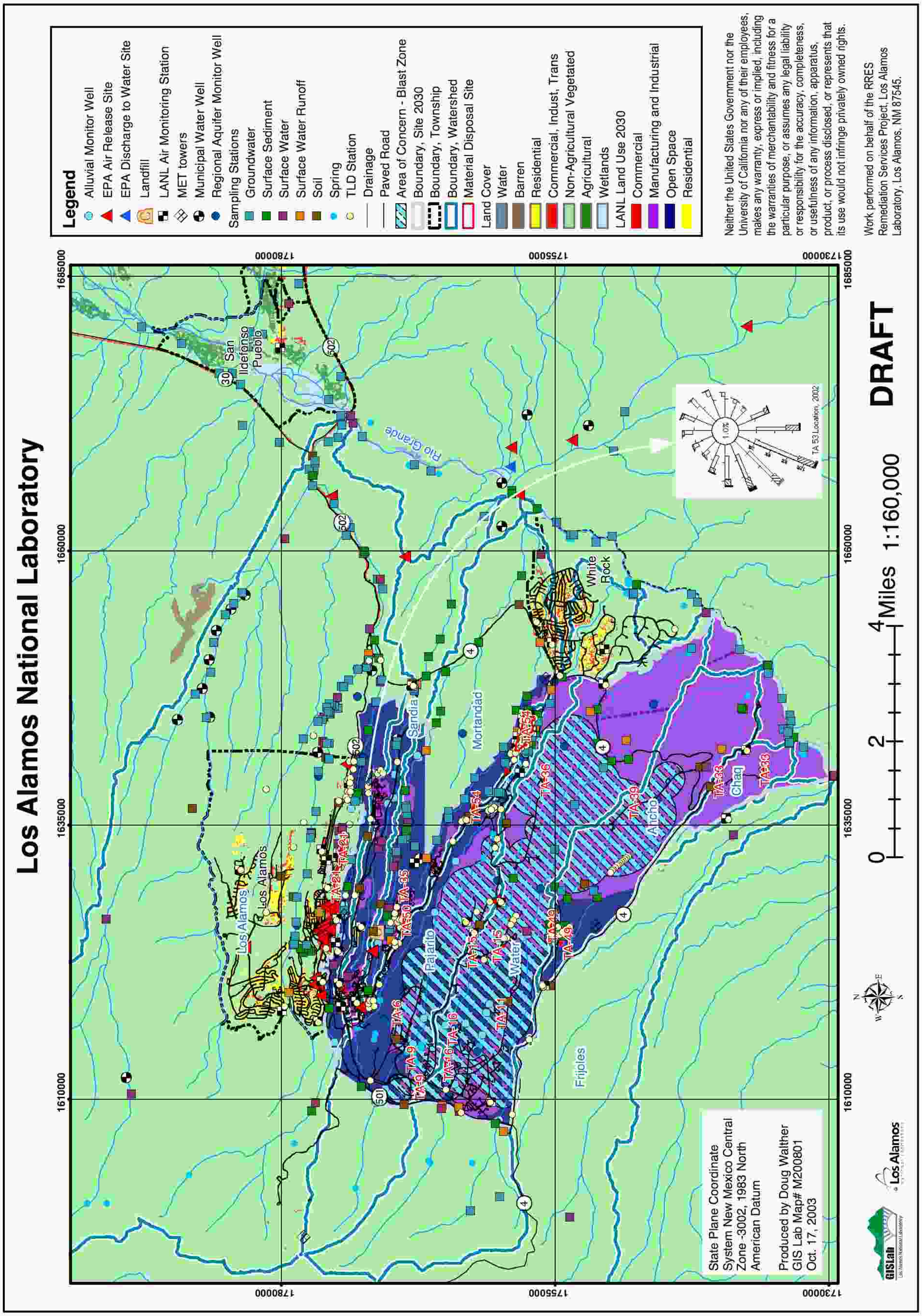


Figure 3.2b. Site human and ecological land use, End state.

In 2035 as in 2003, vacant land designated as Non-Agricultural Vegetated (light green) dominates all other categories of land use around LANL, accounting for 49 percent of the area. Recreational use of accessible lands for hiking, mountain-biking, rock-climbing, and snow-skiing is prevalent, and is expected to remain so.

Due to the semi-arid climate and the local topography, agricultural activities in the area around LANL are limited and are expected to remain so. However, the community of San Ildefonso Pueblo located west-northwest of LANL between highway 30 and highway 502 grows crops for domestic consumption and some local marketing, and also graze livestock on their lands near the LANL boundary.

The following points summarize local agricultural activity:

- A small percentage of land (1 to 2 percent) is used for growing crops.
- Most of the agricultural acreage is irrigated.
- Surface water irrigation is much more common than groundwater irrigation.
- Livestock density is low (1 per 300 acres).

Information regarding anticipated changes in the two population centers (the town of Los Alamos adjacent to the north-central site boundary, and the town of White Rock near the west-central site boundary) were not available at the time that these maps were created, but they are not expected to grow significantly since they are largely populated by families of LANL employees and the number of employees is not expected to increase dramatically.

The municipal water supply for both Los Alamos and White Rock is maintained with water pumped from the regional aquifer, which is approximately 300 m below-ground-surface. The supply wells are operated and maintained by the county of Los Alamos, but are located on LANL property. Water pumped from the wells is stored in above-ground tanks.

The Rio Grande is used extensively for recreational purposes, including fishing and rafting. It is the only significant surface water body near the LANL environs.

3.2.2 Ecological Activities

Ecological activities suggestive of potential ecological exposure points and receptors are partially inferred from knowledge of local conservation areas, threatened and endangered species buffer zones, watersheds, wetlands, vegetation coverages, and habitat ranges.

The plants and animals native to the Los Alamos region designated as Non-Agricultural Vegetated (light green) are diverse, partly because of the large elevation gradient between the Rio Grande (1500 m above sea level) and the Jemez Mountains (2,100 m above sea level) and also because of the canyon and mesa terrain. One-seed juniper and piñon pines are the dominant tree species in undisturbed areas. Common shrub species include big sagebrush (Artemisia tridentata), wax currant (Ribes cerceum), four-wing salt bush (Atriplex canescens), currant (Ribes sp.), and mountain mahogany (Cercocarpus betuloides).

Blue grama grass (Bouteloua gracilis), cryp-togamic soil crust, and prickly pear cactus (Opuntia spp.) are the most common low-growing (understory) plants on the mesa top. Other common understory plants include snake weed (Gutierrezia microcephala and Gutierrezia sarothrae), pinque (Hymenoxys richardsonii), wild chrysanthemum (Bahia dissecta), leafy golden aster (Chrysopsis filiosa), purple horned-toothed moss (Ceratadon purpureus), several lichen species, three-lawn grass (Aristida spp.), bottlebrush squirreltail (Sitanion hystrix), bluegrass (Poa spp.), false tarragon (Artemisia dracunculus), and a species of Mammalaria cactus.

As a result of LANL operations, many of the native under-story plants within the LANL boundary are being replaced by exotic species. Recently disturbed areas support plants such as goosefoot (Chenopodium fremontii), tumbleweed (Salsola kali), cutleaf evening primrose (Oenothera caespitosa), common sunflower (Helianthus anuus), and other colonizing species.

Insects, reptiles, mammals, and birds inhabit the Pajarito Plateau. Harvester ants are the most abundant insect, while common reptiles include fence lizards (Sceloporous undulatus), Plateau striped whiptails (Cnemidophorus velux), gopher snakes (Pituophis melanoleucus), and garter snakes (Thamnophilis elegans). Many mammals inhabit the Pajarito Plateau, including rodents, mule deer, elk, black bear, mountain lion, bobcat, fox, and coyote. The plateau supports a wide variety of bird species. In addition to a range of songbirds, a variety of nesting and migrating raptors have been identified in less-disturbed areas of the canyons. Burrowing animals are common to the mesa tops across the Plateau.

3.2.3 Significant Differences between the Current State and the End State Maps

The major visible differences in the attributes considered by DOE to represent Human and Ecological Land Use now and in the year 2035 are:

- The change in land-use designation from Open Space in 2003 (dark blue) to Manufacturing and Industrial in 2035 (magenta-pink) in the southern-most portion of the LANL boundary.
- The reduction of land within the north-central (grey outlined light green irregular polygon) and north-northeast (dark blue “hook”) site-boundary in 2003, shown as Non-Agricultural Vegetated (light green) in 2035, corresponding to land parcels that will be transferred from DOE within the next decade.

3.3 Site Context Legal Ownership

The maps shown in Figures 3.3a and Map 3.3b show the current and predicted legal ownership of the lands surrounding LANL. Refer to section 3.1.1 for additional details on land ownership and control. The major differences between the maps representing the current state and the end state are associated with land transfer, as discussed earlier.

3.4 Site Context Demographics

The maps shown in Figures 3.4a and Map 3.4b show the current and predicted population density of the lands surrounding LANL.

3.5 Conceptual Site-Wide Exposure Model

A conceptual site-wide exposure model identifies potential sources of contamination, relevant pathways for transport, and likely pathways for exposure based on current knowledge of the distribution of contaminants in environmental media. The transport pathway descriptions include the predominant release mechanisms, transport processes, and the contaminated media for each transport pathway.

This section begins by describing characteristics of the natural environment within which LANL operates that play a role in the risks posed by contaminants released in air or on or below the land surface. Figure 3.5 is a false-color satellite image of the site, which illustrates the rather dramatic surface features that impact the transport of contamination within the environment, and therefore play a major role in controlling the risks associated with environmental hazards. Some of the more important impacts associated with the hydrogeology include:

- The mesa-canyon topography; which affects air, surface water, and subsurface contaminant transport, as well as potential contaminant receptors.
- The geology, consisting of subsurface layers of various volcanic depositions, which has variable physical and chemical features that affect subsurface contaminant transport.
- The hydrology, incorporating intermittent surface streams in adjacent canyons, liquid- and vapor-phase water moving through the subsurface within the rock matrix, within fractures in the rock, and along interfaces between layers, and from transpiration, all of which affect surface and subsurface transport of contaminants.

That narrative description is followed by a graphical depiction of the conceptual site-wide exposure model, which identifies environmental processes that may transport contaminants within the environment, potentially resulting in harmful exposures. The conceptual site-wide exposure model groups the hazards discussed previously in this section into generic Hazard Categories, which are:

- Hazard Category A: Airborne (largely operational hazards, including stack emissions, burning sites, and explosives-firing sites)
- Hazard Category B: Surface (both operational and legacy sources including liquid effluents, chemical spills, intact waste containers, and industrial and manufacturing operations)

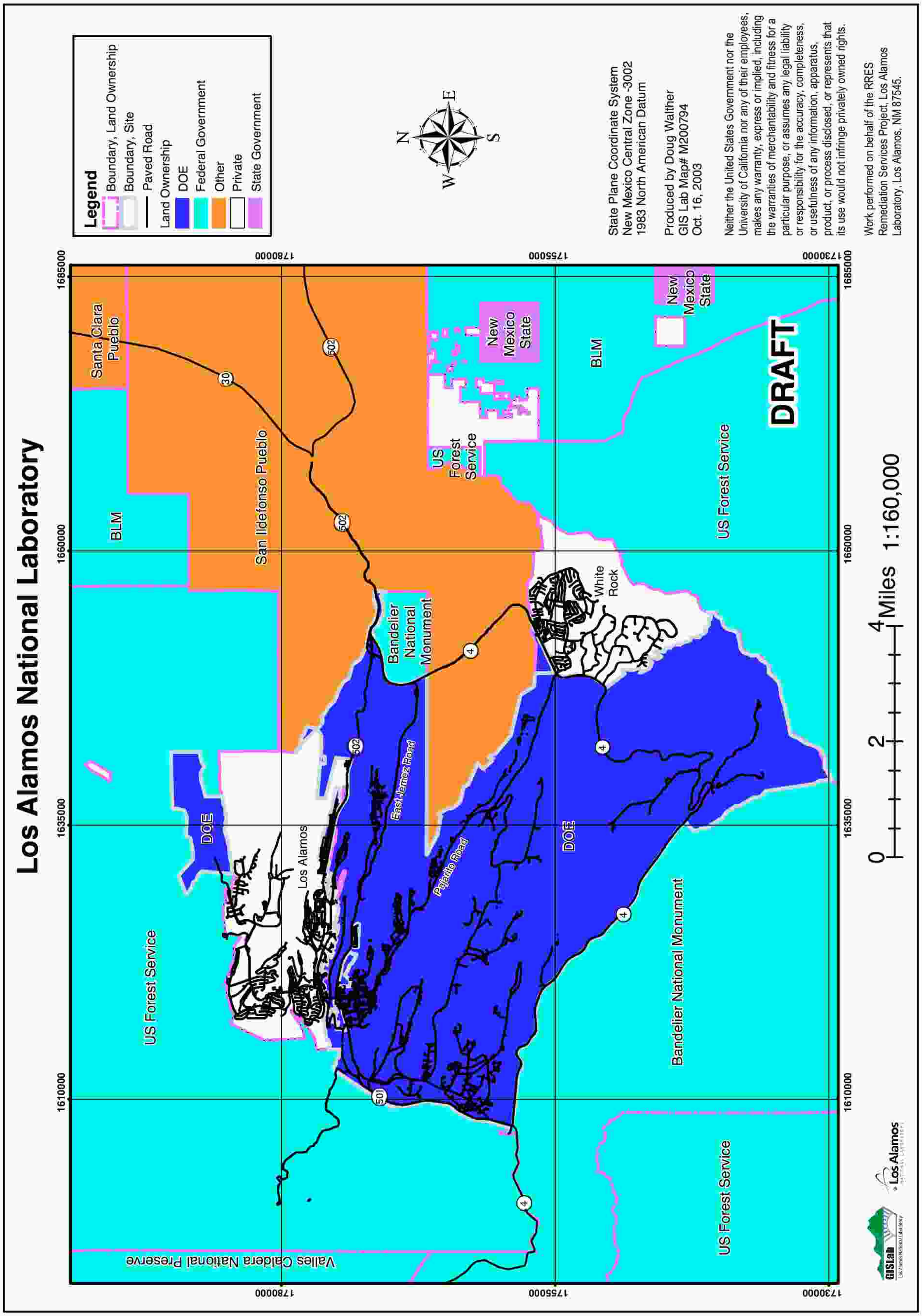


Figure 3.3a. Site legal ownership, Current state.

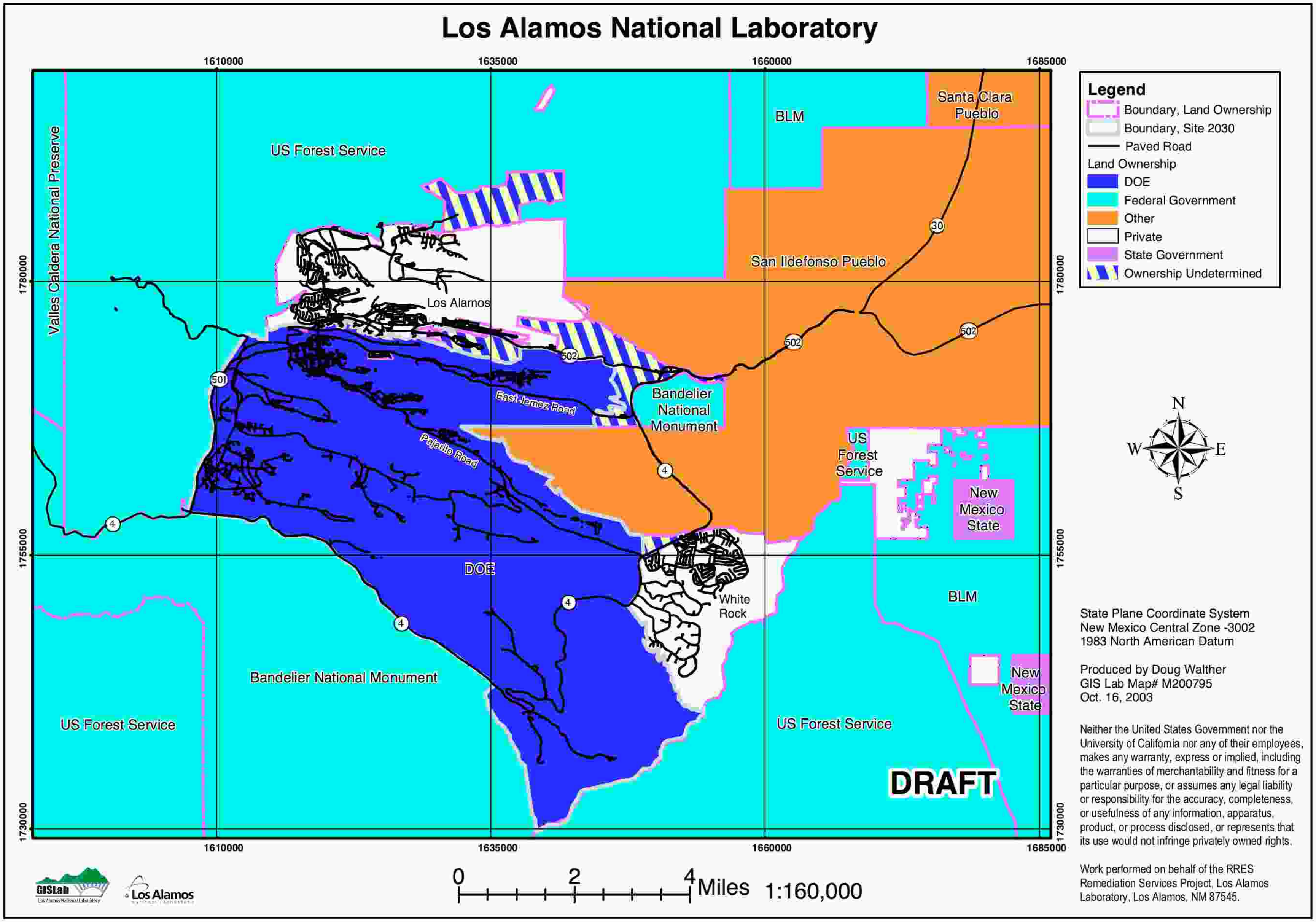


Figure 3.3b. Site legal ownership, End state.

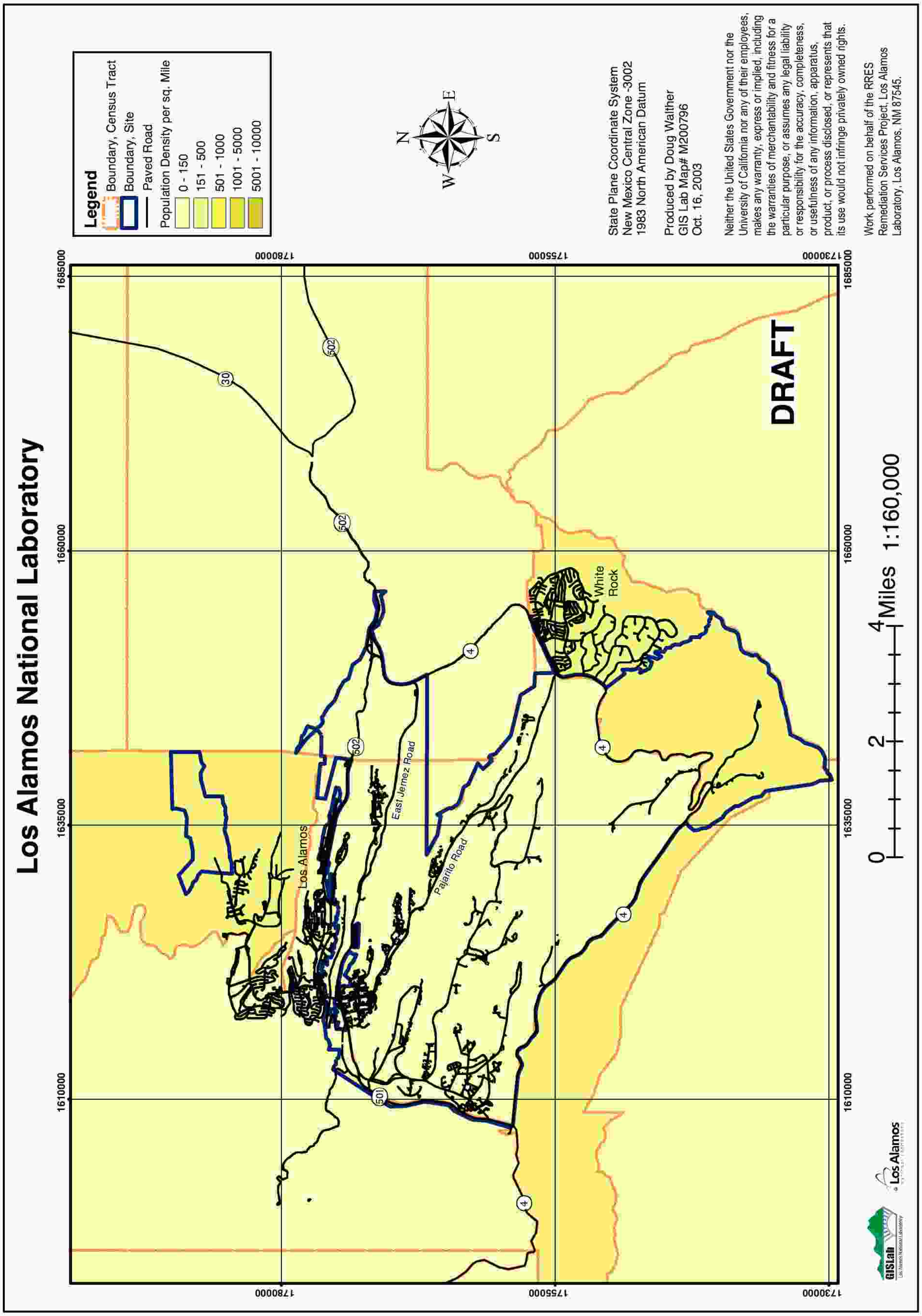


Figure 3.4a. Site demographics, Current state.

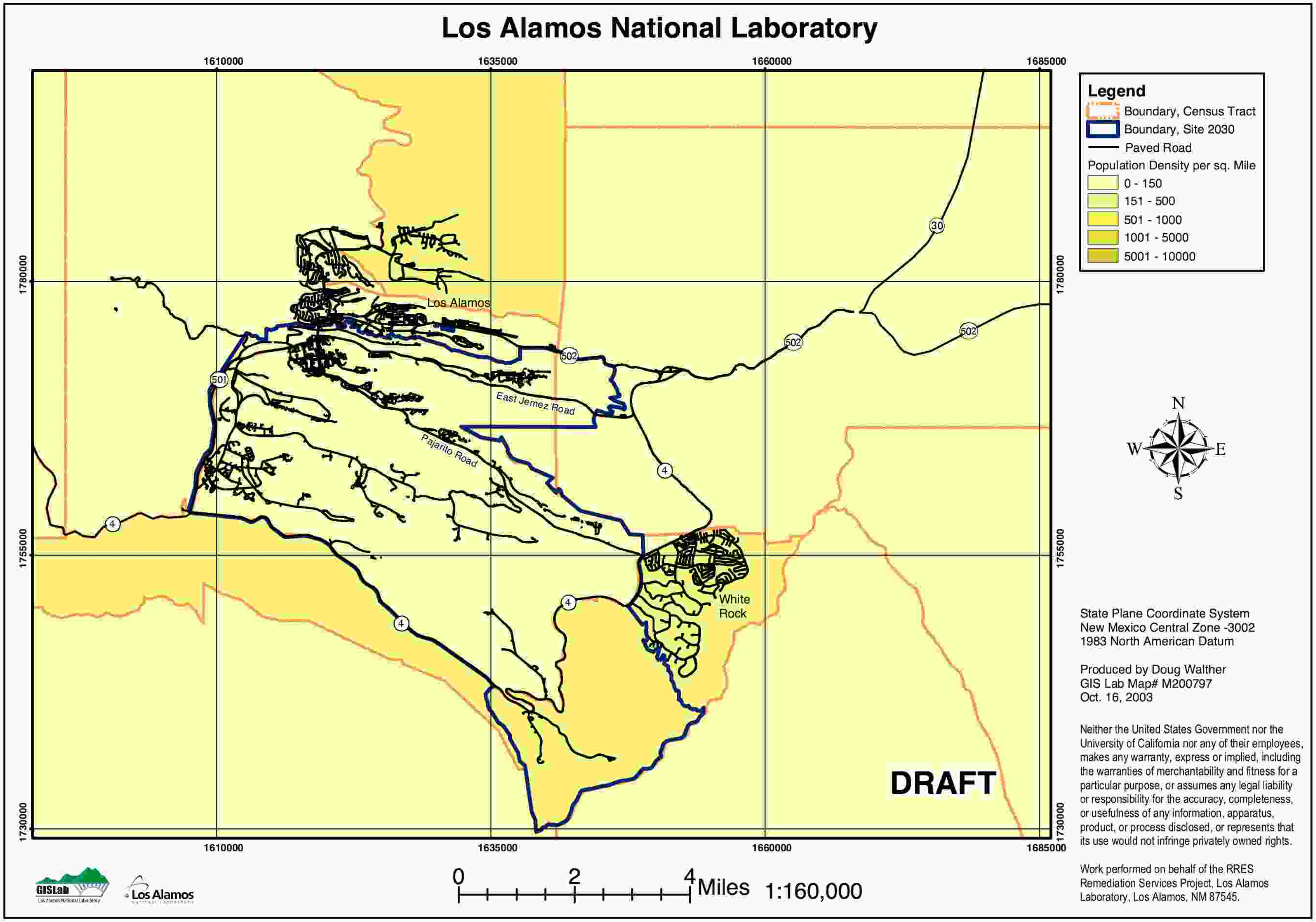


Figure 3.4b. Site demographics, End state.

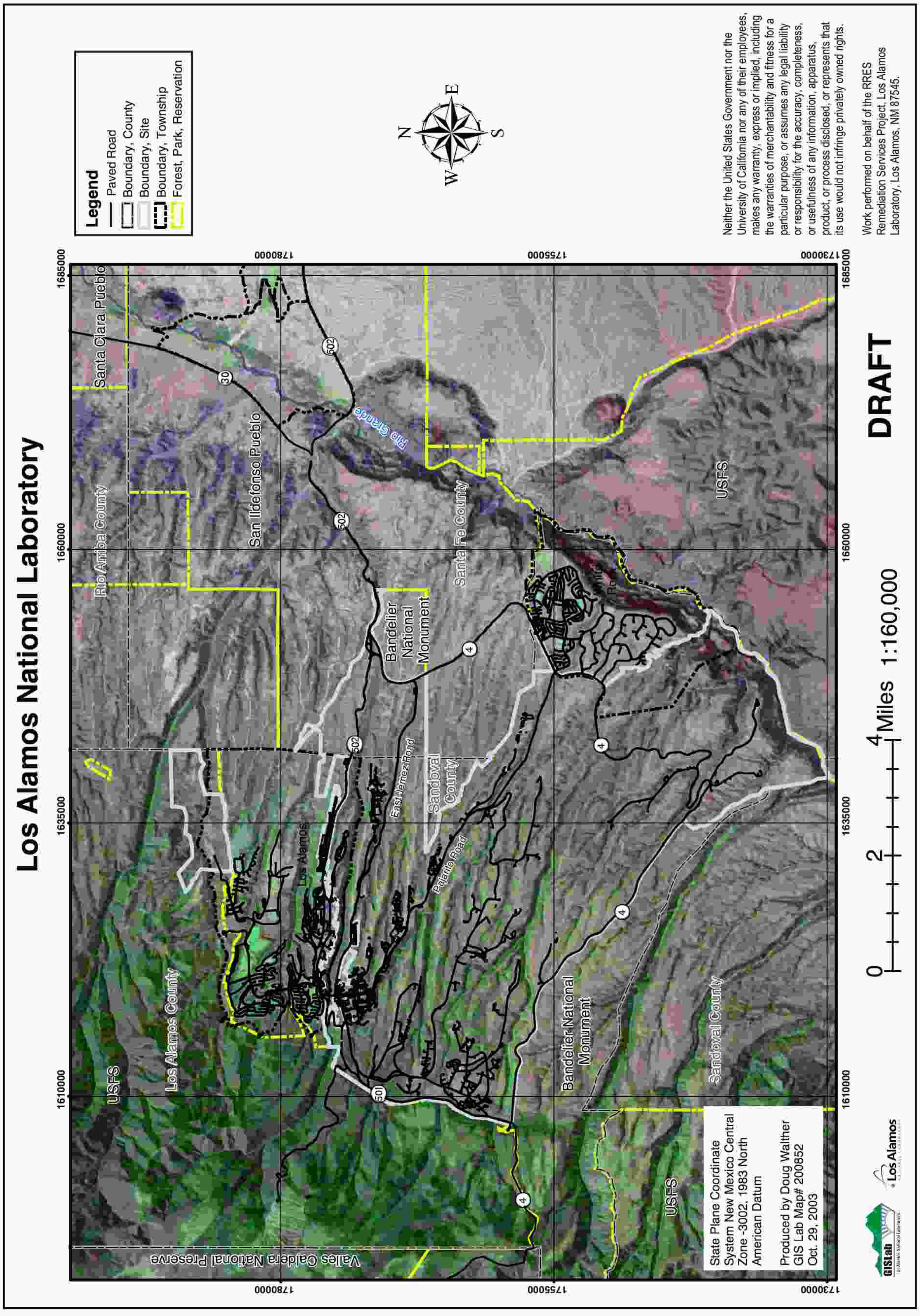


Figure 3.5. Site Landsat photo and surface interface.

- Hazard Category C: Subsurface (both operational and legacy sources including MDAs, septic tanks, and evaporation lagoons).

Environmental Setting

LANL is located on the Pajarito Plateau in north central New Mexico. The 43 mi^2 (112 km^2) plateau slopes gently to the east-southeast between the Jemez Mountains on the west and the broad Grande Valley on the east, which runs north to south. Elevations range from 7600 to 6300 ft (2317 to 1920 m) above mean sea level. The local relief of the plateau consists of east-southeast-trending canyons and mesas. This section of the document describes the natural features and events of the region, focussing on those that may impact the release or transport of contaminants.

Climate

The Pajarito Plateau has a temperate semiarid mountain climate. Spring is typically windy and dry. Summer begins with warm, usually dry conditions in June, followed by a two-month rainy season in July and August. The rainy season ends in autumn when the climate becomes drier, cooler, and calmer, and winters are generally mild with occasional winter storms.

Meteorological variables at the Laboratory are measured at five towers on the Pajarito Plateau. Four of the towers are located on mesas and one tower is located in Los Alamos Canyon. Local and regional topographical features significantly influence the local meteorology of the LANL area (Baars et al. 1998,

The elevation of the Pajarito Plateau is the primary influence of temperature; the plateau is cooler in the summer than the surrounding low-lying desert. In the evenings and at night, cool air sinks off the plateau and flows down the canyons; thus, nighttime temperatures on the mesas are often warmer than in the

canyons and at lower elevations. The general lack of moisture in the atmosphere also influences temperature. With less moisture, there is less cloud cover, which allows a significant amount of solar heating during the daytime and radiative cooling during the nighttime. This heating and cooling causes a wide range of daily temperatures. The average range is 13°C (LANL 1998, 59904).

The average annual precipitation, from rainfall and the water equivalent from frozen precipitation, is 47.6 cm (18.7 in.). However, the annual total fluctuates considerably from year to year, with the standard deviation of the fluctuation being 12.2 cm (4.8 in.). The lowest recorded annual precipitation is 17.3 cm (6.8 in.) and the highest is 77.1 cm (30.3 in.). The maximum precipitation recorded for a 24-h period is 8.8 cm (3.5 in.) and the maximum for a 15-minute period is 2.3 cm (0.9 in.). The eastern portion of the plateau often receives 13 cm (5.1 in.) less annual precipitation than the west-central portion of the plateau. About 36% of the annual precipitation falls during the July/August rainy season.

Winter precipitation occurs mostly as snow. The annual snowfall averages 150 cm (59 in.) but from year to year the amount of snow is quite variable. The highest recorded snowfall for one season is 389 cm (153 in.), and the highest recorded snowfall for a 24-h period is 56 cm (22 in.). In a typical winter there are 14 days during which snowfall exceeds 2.6 cm (1 in.) and 4 days of snowfall exceeding 10.2 cm (4 in.). The most extreme single-storm snowfall on record is 122 cm (4 ft).

Relative humidity varies considerably daily, but monthly averages vary little during the year. Relative humidity ranges from 39% in June to 56% in December, and averages 51% over the entire year. Absolute humidity ranges from 2.4 g of water/m^3 of air in January to 8.7 g/m^3 in July and August, when moist subtropical air invades the region during the rainy season. Fog in the Pajarito Plateau area is very rare, occurring less than five times a year on average.

Wind conditions on the Pajarito Plateau are generally light, and the average annual wind speed is 2.5 m/s (5.5 mi/h). However, the windy season from mid-March to early June sustains wind speeds exceeding 4 m/s (8.8 mi/h) 20% of the time during the day and the daily maximum wind gust exceeds 14 m/s (31 mi/h) about 20% of the time. The highest wind gust on record is 343.4 m/s (77 mi/h). Tornadoes have not touched the ground in the Pajarito Plateau area; however, funnel clouds have been observed in Los Alamos and Santa Fe Counties.

Winds over the Pajarito Plateau show considerable spatial structure and temporal variability. During sunny, light-wind days, an upslope flow greatest along the western margin of the plateau usually develops over the plateau in the morning. By midday a southerly flow usually prevails over the entire plateau.

The prevailing nighttime winds over the western portion of the plateau are west-southwesterly to northwesterly. These nighttime westerlies result from cold air drainage off the Jemez Mountains and the Pajarito plateau; the drainage layer is typically 50 m (165 ft) deep in the vicinity of Technical Area (TA) 6. At stations farther from the mountains, the nighttime direction is more variable but usually has a relatively strong westerly component. Just above the drainage layer, the prevailing nighttime flow is usually southwesterly.

Observations made at meteorological stations in canyons show that atmospheric flow there is quite different from flow over the mesas. During the nighttime, cold air flows down the canyons about 75% of the time. This gravity flow is steady and continues for an hour or two after sunrise when it abruptly ceases and is followed by an unsteady up-canyon flow for a couple of hours.

Solar irradiance measurements show that Los Alamos receives more than 75% of possible sunshine annually. (Possible sunshine is defined as the amount received when the sky is cloud-free.) During most of the year, when there is no snow on the ground, about 80% of this incoming solar energy is absorbed at the ground surface. About half of this absorbed shortwave energy is offset by longwave radiation to space. The remainder of the radiant energy, called the net all-wave radiation, is dissipated into the soil, into the lower layer of the atmosphere, and evaporates water from the soil and plants (evapotranspiration). Preliminary analyses suggest that monthly total evapotranspiration reaches a maximum of 7.4 cm (2.9 in.) in July. Monthly totals during January and February are about 0.8 cm (0.3 in.). It appears that evapotranspiration equals approximately 90% of the annual precipitation.

Geology

The surface distribution of bedrock geologic units in the Pajarito Plateau area is shown on geologic maps The principal bedrock units in the Pajarito Plateau area consist of the following, in ascending order:

- Puye Formation: and basalts of the Cerros del Rio volcanic field on the east.
- Otowi Member of the Bandelier Tuff and volcaniclastic sediments of the Cerro Toledo interval
- Tshirege Member of the Bandelier Tuff

The Puye Formation is mostly a fanglomerate deposit generally consisting of poorly sorted boulders, cobbles, and coarse sands. At PM-3 the clasts are composed of dacite, rhyolite, and fragments of basalt and pumice. At TW-8 in Mortandad Canyon, the fanglomerate consists predominately of fine- to coarse-grained sands and interbedded clay, silt, and gravel. The lower fanglomerate includes more than 95 ft (29 m) of light tan to light gray tuff and tuffaceous sand.

The top of the regional zone of saturation beneath the Pajarito Plateau is usually encountered within the fanglomerate facies of the Puye Formation and the associated interbedded basalts.

The Otowi Member of the Bandelier tuff erupted approximately 1.6 million years ago. The Otowi Member varies in reported thickness from 184–465 ft (56–142 m). The deposits of the Otowi Member beneath upper Sandia and middle Mortandad watersheds are among the thickest on the Pajarito

The basal part of the Otowi Member includes the Guaje Pumice Bed, which is a sequence of well-stratified pumice-fall and ash-fall deposits. The Guaje Pumice Bed typically is 30- to 35- ft- (9.1- 10.7-m) thick beneath the Pajarito Plateau.

The Tshirege Member of the Bandelier Tuff erupted approximately 1.2 million years ago. It is a multiple-flow ignimbrite sheet that forms the prominent cliffs and mesas of the Pajarito Plateau. The Tshirege Member includes a number of subunits that can be recognized based on differences in physical and weathering properties.

Subunits of the Tshirege Member dip gently southeastward on the Pajarito Plateau. The southeastward dip of these tuffs probably is the primary initial dip, mainly resulting from the burial of a southeast-dipping paleotopographic surface and thinning of subunits away from the volcanic source to the west.

Hydrology

Rivers and streams located within 80 km (53 mi) of LANL include the Rio Grande and its tributaries including the Chama, Ojo Caliente, Santa Cruz, Nambe, and Tesuque rivers to the north and east; the Jemez River and San Antonio creeks to the west; and the Santa Fe and Galisteo rivers to the south. The Rio Grande receives all surface water drainage from the Pajarito Plateau. Reservoirs within 80 km (50 mi) include the Cochiti, Abiquiu, Santa Cruz, and Jemez.

Despite the dramatic erosional topography of the Pajarito Plateau that resulted from greater surface flows in the past, only a few streams currently flow year-round; most flow only after heavy rains and snowmelt. Run-off from heavy rainfall and snowmelt reaches the Rio Grande several times a year in some drainages.

Springs occur at elevations between 2,400- and 2,700-m (7,900- and 8,900-ft) on the eastern slopes of the Jemez Mountains and supply water to the upper reaches of several major canyons, which is depleted by evaporation to the atmosphere and infiltration into the underlying alluvium. On the mesas, water flows only as stormwater and snowmelt run-off. As a result of run-off, surface erosion occurs, typically as shallow sheet erosion on the relatively flat parts of the mesa, or by local established erosion channels during sustained storm run-off.

Run-off from summer storms reaches a maximum in less than 2 hours and lasts less than 24 hours. In contrast, run-off from spring snowmelt occurs over a period of several weeks at a low discharge rate. The amount of eroded material transported in run-off waters is generally higher in summer rainfall events than during snowmelt.

Groundwater in area occurs as shallow perched alluvial groundwater in canyons, intermediate perched zones beneath some canyons and along the Jemez Mountains within the Bandelier Tuff, the Cerros del Rio Basalt, and the upper part of the Puye Formation, and in the regional aquifer. The regional aquifer is the only source capable of serving municipal and industrial water needs.

Ephemeral streamflows in the canyons of the Pajarito Plateau have deposited alluvium that locally may be up to 100-ft-(30 m) thick and typically more permeable than the underlying volcanic tuff and sediments. Ephemeral run-off in some canyons infiltrates the alluvium until downward movement is impeded by the less permeable underlying strata, which results in a buildup of shallow alluvial groundwater. In addition to the alluvium, in some cases relatively thin zones of shallow groundwater can also be contained in the weathered tuff or some other unit immediately underlying the alluvium.

Perched groundwater is known to exist beneath several canyons in the eastern portion of the Laboratory, along the eastern flanks of the Jemez Mountains west of the Laboratory, and beneath the mesas and canyons at S Site (TA-16), located in the southwestern part of the Laboratory near the Jemez Mountains. Perched groundwater zones possibly exist beneath other canyons in the south and central portions of the Laboratory.

Water for LANL, the communities of Los Alamos and White Rock, and Bandelier National Monument is supplied from 11 deep wells in 3 well fields. The wells are located on the Pajarito Plateau and in Los Alamos and Guaje canyons east of the plateau. Municipal and industrial water supply pump volume during 1997 was 1.29 billion gal. (4.9 billion l). Yields from individual wells ranged from about 175–1400 gal./min (665–5320 l/min) (Stoker et al. 1992, 12017).

Typically, most of the units of the Tshirege Member, which form the mesas and slopes on the Plateau, are very dry and do not readily transmit moisture. However, relatively thin subunits such as pumice falls, surge beds, and the Colonnade Tuff demonstrate elevated moisture contents and enhanced fluid-flow properties. Most of the pores in the tuff are small enough to be of capillary size, and hold water against gravity by surface tension forces. Moisture content is generally more variable near the top of the mesa than in the central portions as a result of variations in temperature, humidity, and evapotranspiration. Vegetation is very effective at removing moisture near the surface by transpiration. During the summer rainy season when rainfall is highest, near-surface moisture content is variable due to the effects of higher rates of evaporation and of transpiration by vegetation, which flourishes during this time.

The volumetric moisture content within mesas varies between about two and 14 percent. Measurement on core samples show that the surge beds at the base of Unit 2 have relatively high capillary suction and low hydraulic pressure. The interpretation of these measurements is that moisture is being drawn towards the surge beds from above and below. The driving force for this movement may be evaporation aided by air movement along the fractures within these units or along the more permeable surge beds found at the base of Unit 2. Similar surge beds are found at the Unit 3/4 interface, also; less is known about the air permeability there.

3.5.1 Current State

Figure 3.5.1a is a conceptual site-wide exposure model, which integrates in a simple diagram the features, events, and processes characterizing the current state, as discussed in the previous sections, in the specific context of risk- the likelihood of harmful exposures to contaminants in the environment. The Hazard Category box on the left side of the figure represents contaminants that are introduced directly into:

- air (Hazard Category A),
- onto the surface of the ground (Hazard Category B), or
- below the surface of the ground (Hazard Category C).

Hazard Categories are analogous to what are loosely referred to as primary sources, recognizing the subtlety that sources become hazards when they enter the environment. Under current conditions, Hazard Categories A and B are associated primarily with operational releases discussed in Section 3.1.4, while Hazard Category C is associated with both active and formerly-used MDAs.

The arrows emanating from each Hazard Category represent environmental transport pathways that may move contamination from the directly affected medium to one or more media, which become indirectly contaminated, represented by the boxes to the left of center on the figure. The arrows between indirectly contaminated media represent the systematically integrated pathways that may move contamination within the environment. The arrows pointing right from the indirectly contaminated media to the matrix on the right of the figure indicate exposure pathways whereby biological receptors may come into contact with contaminated media. Several of the pathways are particularly important because they provide natural controls (discussed below) over the movement of contaminants. Generally speaking, these natural controls reduce potential exposure-point concentrations to levels below applicable regulatory or risk-based standards.

The line-styles of the arrows differentiate between pathways that are fully controlled (┈┈▶, partially controlled (--▶), and uncontrolled (—▶). As apparent from the figure 3.5.1a, controls ▌▌) can be achieved at any point between the Hazard Category and the exposure point. Controls that occur at the hazard source are examples of EPA's Source Control Performance Measure (cf. Section 1.3.1).

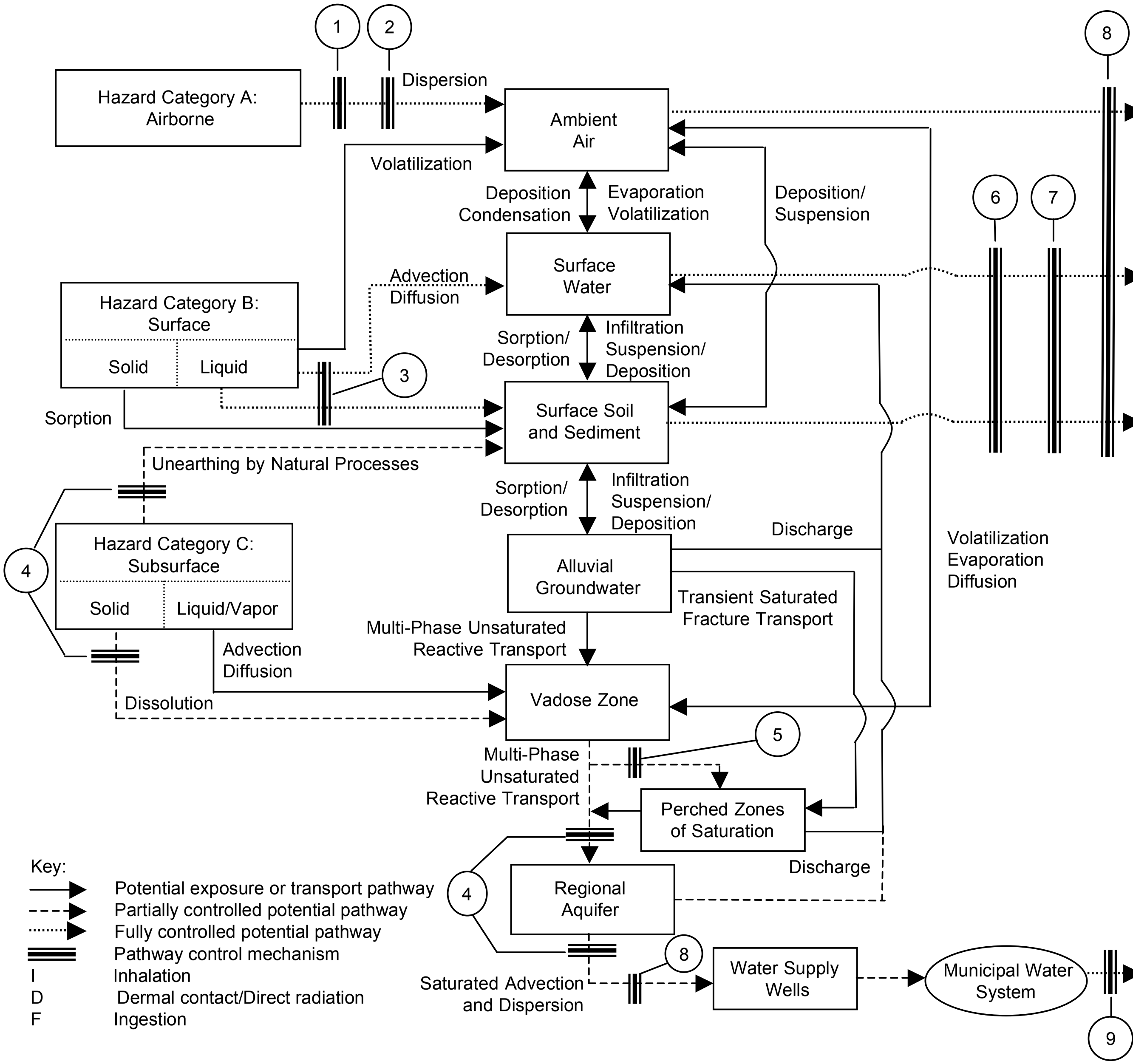
The site-wide conceptual site exposure model shows a number of controls that reduce the risk of hazards under current conditions. Many of these are associated with institutional and administrative controls pursuant to worker safety and environmental protection regulations, while others are attributed to natural characteristics or process at the site that attenuate hazards along the pathway between hazard and receptor. Together, institutional and natural controls provide layers of protection that ensure that the risks due to operational and historical releases of contamination into the environment from LANL are relatively low, as demonstrated on the RCRA Environmental Indicators worksheets included in Appendix 1.

The number tagging each control mechanism in Figure 3.5.1a identifies each control as follows:

1. Source control and monitoring of operational releases of hazardous constituents to air in compliance with NESHAPS regulations provide control of hazard.

2. Source control and monitoring of operational releases of hazardous particulates in air in compliance with OSHA provide control of hazard.

Figure 3.5.1a Site-Wide Conceptual Site Exposure Model– Current State



Potential Exposures

Occupational	Recreational Onsite	Recreational Offsite	Residential	Ecological
I/D	I/D	I/D	I/D	I/D
D/F	D/F	D/F		D/F
I/D/F	I/D/F	I/D/F	I/D/F	I/D/F
D/F			D/F	

3. Source control and monitoring of operational releases of waste water in compliance with NPDES regulations provide control of hazard.
4. Characterization of regional hydrogeology, and monitoring conducted in association with the risk and performance assessment/composite analysis and environmental protection programs provide evidence of natural pathway control, indicating that multiphase unsaturated reactive transport and saturated advection and dispersion ensure that most contaminants (i.e., all but non-reactive species) will *not* be transported from their source to groundwater exposure points by 2035.
5. Characterization data show no perched zones of saturation beneath material disposal areas, but not all have been investigated, providing partial evidence of transport pathway control.
6. Through natural processes, surface water transport of dissolved species is partly retarded by adsorption onto sorptive phases in solid media. Through administrative health and safety procedures, risk-significant worker-exposures to contaminated water, soil and sediment are controlled.
7. Through natural processes, concentrations of contaminants in sediments generally decrease downstream along watersheds (i.e., toward the LANL boundary) due to dilution with clean sediments. Through administrative controls, access at facility boundary provides partial control of potential recreational exposures.
8. Exposure control provided by environmental protection program monitoring and mitigation of potential contamination in air, soil, sediment, groundwater, and springs.
9. Exposure control provided by monitoring of municipal water supply.

Table 3.5-1 provides a contextual definition of each of the indirectly contaminated media, and descriptions of and hypotheses associated with, the pathways included in Figure 3.5.1a.

Table 3.5-1.
Definitions, descriptions, and hypotheses of media and pathways in the current-state site-wide conceptual exposure model

Indirectly Contaminated Medium	**Contextual Definition**
Ambient Air	Refers to the earth's atmosphere as a media for contaminant transport.
Surface Water	Includes perennial and ephemeral stream reaches (both naturally occurring and effluent-driven), groundwater discharged via springs, surface impoundments and ponds, and stormwater flow derived from short, intense, precipitation events and snowmelt.
Surface Soil and Sediment	Includes naturally occurring soil and anthropogenically placed backfill materials present on mesa tops, and soils and sediments present on mesa slopes and canyon bottoms, both naturally occurring and derived from mesa tops.
Vadose Zone	Unsaturated media located between the ground surface and locally present groundwater, whether the groundwater is present at alluvial, intermediate, or regional aquifer depths.
Alluvial Water	Unconfined surface or near-subsurface zones of saturation in unconsolidated surface sediments in canyons, perched high above the regional aquifer.
Perched Zones of Saturation	Includes occurrences of perched groundwater bodies of varying extent and depth.
Regional Aquifer	Groundwater present in the regional zones of saturation, which typically occur in the Puye Formation, sediments of the Santa Fe Group, Cerros del Rio Basalts, and the Tschicoma Formation.
Transport or Exposure Pathway	**Description/Hypothesis**
Advection	Dissolved contaminants moving with the bulk flow of water.
Condensation	Concentration and settling of vapor-phase airborne contaminants onto surface media.
Deposition	Gravity-driven settling of suspended particulate contaminants from air or surface water onto surface media, or from groundwater onto solid confining solid media.
Desorption	Re-dissolution of solutes that were bound to solid phases of geologic media.
Diffusion	Movement of dissolved contaminants in liquid water and volatile contaminants in air from areas of higher concentration to areas of lower concentration.
Discharge	Groundwater migrating to the surface due to physical forces
Dispersion	Atmospheric distribution of airborne contaminants controlled by temperature and pressure gradients, wind speed and direction, and precipitation, and surface- and groundwater distribution of solutes in a saturated conditions.
Dissolution	Chemical reaction with surface water or groundwater, causing a solid-phase contaminant to disperse into liquid water as a solute.
Evaporation	Conversion of liquid water and volatile contaminants to vapor phases due to contact with ambient air. Pore water evaporation appears to occur deep within mesas due to barometric pumping.
Infiltration	Flow of surface water and solutes into surface media through pores or small openings.
Matrix (unsaturated) flow	Steady-state movement of liquid water and solutes, and colloids smaller than the pore space, through the pore spaces in unsaturated rock.
Microbial Degradation	Decomposition by microscopic organisms.
Mineralization	Organic materials naturally transformed into inorganic materials.
Multi-Phase Unsaturated Reactive Transport	Matrix transport coupled with contaminant-specific processes like radioactive decay, microbial degradation, sorption/desorption, mineralization, and evaporation.

Transport or Exposure Pathway	Description/Hypothesis
Sorption	Dissolved contaminants in subsurface binding to natural components of the solid porous media, and onto the surface of soil and sediment particles that can be transported by runoff and concentrated in depositional areas in the canyons.
Suspension	Precipitation runoff, surface water flow, and effluent discharge moving contaminants as particles into the canyon stream or groundwater.
Transient Saturated Fracture Transport	Relatively rapid infiltration, transient flow, and transport in the subsurface through cooling joints and faults in bedrock.
Unearthing by Natural Processes	Re-exposure of subsurface materials by natural processes such as (but not limited to) biotic intrusion, surface erosion, and mass wasting. *Anthropogenic excavation is excluded*.
Volatilization	The direct release of solutes to the atmosphere.

The columns in the matrix on Figure 3.51 indicate the land-use scenarios under which exposures may occur under current conditions, and the letters within the matrix cells indicate the routes of exposure consistent with the exposure scenarios and exposure pathways.

3.5.2 End State

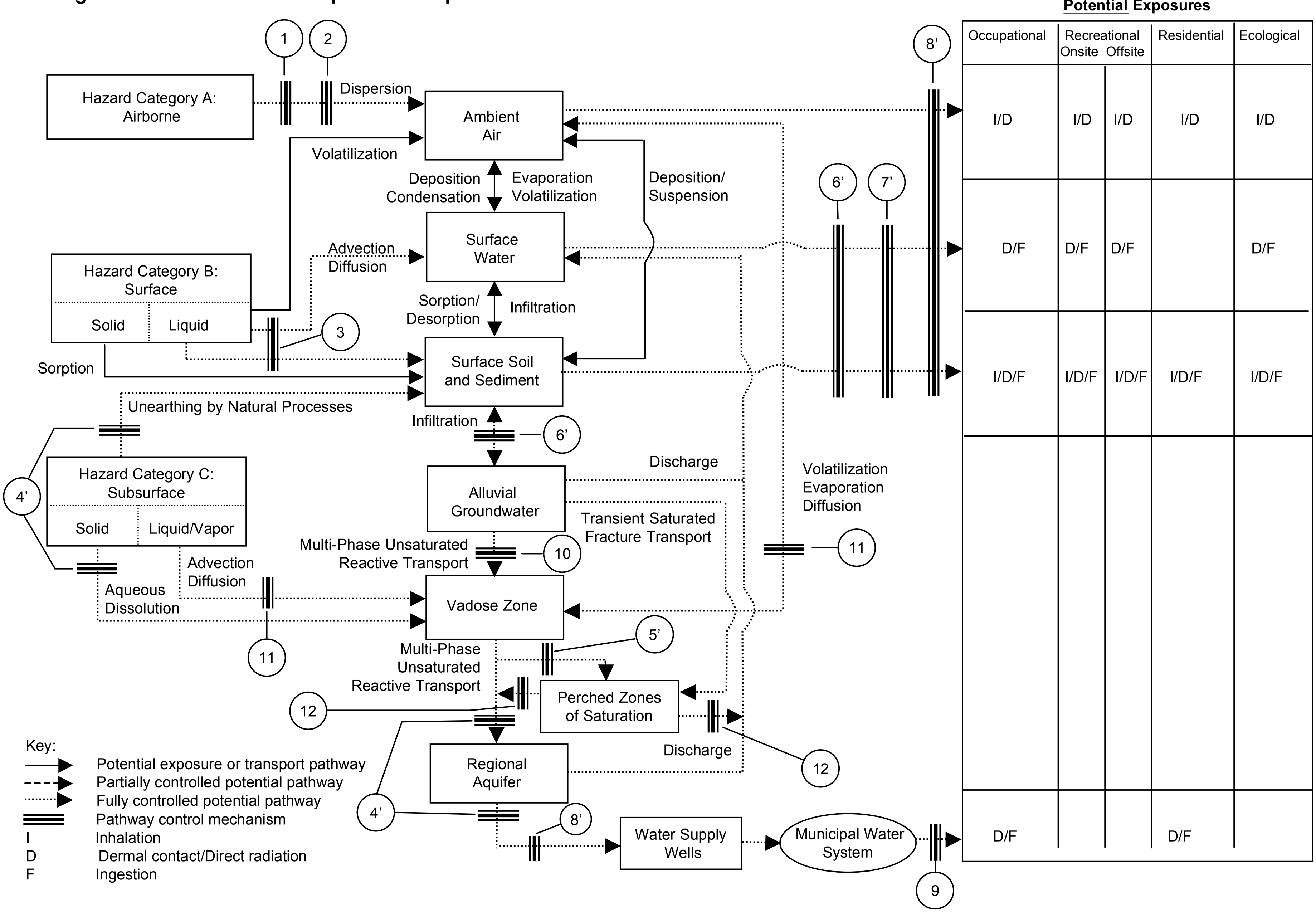
Figure 3.5.1b shows the conceptual site-wide exposure model for end-state conditions expected to be achieved through LANL's EM-sponsored cleanup project and maintained through LANL's NNSA-sponsored environmental management system (which will incorporate long-term environmental stewardship responsibilities, as discussed in Section 1.3.5). The potentially impacted media and transport and exposure pathways active in the current state conceptual exposure model and listed in Table 3.5-1 apply equally to the risk-based end state.

Many of the uncontrolled and partially controlled transport and exposure pathways identified in the current-state are fully controlled. The numbers with prime symbols (i.e., 1' through 8') signify enhancements of controls identified in the current state conceptual site-wide exposure model. In particular, the institutional monitoring and mitigation will meet the requirements of DOE Order 450.1 for systematic site-wide monitoring to ensure the early identification of, and appropriate response to, potential adverse environmental impacts associated with DOE operations, including effluent and surveillance monitoring. Consistent with guidance on annual reporting of site-wide monitoring, results will be differentiated according to NESHAPS and NPDES compliance monitoring, remediation performance monitoring, waste management monitoring, and environmental surveillance monitoring.

1. Source control and monitoring of operational releases of hazardous constituents to air in compliance with NESHAPS regulations provide control of hazard.
2. Source control and monitoring of operational releases of hazardous particulates in air in compliance with OSHA provide control of hazard.
3. Source control and monitoring of operational releases of waste water in compliance with NPDES regulations provide control of hazard.

4'. Characterization of regional hydrogeology, and monitoring conducted in association with the risk and performance assessment/composite analysis and environmental protection programs provide evidence of natural pathway control, indicating that multiphase unsaturated reactive transport and saturated advection and dispersion ensure that most contaminants (i.e., all but non-reactive species) will *not* be transported from their source to groundwater exposure points by 2035. Major MDAs are capped and monitored within the institutional environmental management system. Groundwater is monitored to detect contaminants at specific levels and locations established to provide time to respond before contaminants reach supply wells, springs, or the Rio Grande.

Figure 3.5.1b Site-Wide Conceptual Site Exposure Model– End State



5'. Perched zones beneath material disposal areas are characterized and accounted for in risk-based end state (including regulatory standards and final risk goal).

6'. Through natural processes, surface water transport of dissolved species is partly retarded by adsorption onto sorptive phases in solid media. Contaminated soil and sediment removed, treated, or stabilized as necessary to achieve risk-based end state (including regulatory standards and final risk goal).

7'. Through natural processes, concentrations of contaminants in sediments generally decrease downstream along watersheds (i.e., toward the LANL boundary) due to dilution with clean sediments. Institutional access controls are enhanced, as necessary to achieve end-state risk goal (including regulatory performance standards and final risk goal).

8'. Exposure control provided by environmental protection program monitoring and mitigation of potential contamination in air, soil, sediment, groundwater, and springs. An integrated site-wide groundwater-monitoring program will be designed and implemented to ensure early detection of risk-significant contaminants from all Hazard Categories as necessary to maintain the end-state risk goal.

9. Exposure control provided by monitoring of municipal water supply.

10. Contaminated alluvial groundwater treated and monitored as necessary to achieve end-state risk goal (including regulatory performance standards and final risk goal).

11. Subsurface vapor sources are controlled by soil vapor extraction as necessary to meet source-control performance standards, and MDAs are monitored and contingency responses implemented as necessary to achieve risk-based end state (including regulatory standards and final risk goal).

12. Contaminated perched zones are monitored and contingency responses implemented as necessary to achieve risk-based end state (including regulatory standards and final risk goal).